United States Patent

Kaufman

[15] **3,689,144**

[45] **Sept. 5, 1972**

[54] **ELECTROSTATIC COPYING APPARATUS EMPLOYING DEVELOPMENT ON SIDE OF THE IMAGING SHEET OPPOSITE THE PHOTOCONDUCTIVE COATING**

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[22] Filed: **Jan. 28, 1971**

[21] Appl. No.: **110,511**

Related U.S. Application Data

[62] Division of Ser. No. 17,810, March 9, 1970, Pat. No. 3,594,159.

[52] **U.S. Cl.** .....**355/3,** 355/10, 355/12, 117/37 LE

[51] **Int. Cl.** **G03g 15/06**

[58] **Field of Search** ....355/3, 10, 17; 96/1; 117/17.5, 117/37 LE

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Assistant Examiner—Alan A. Mathews
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[57] **ABSTRACT**

Apparatus for electrostatic reproduction of indicia, wherein a sheet of record material having an insulating substrate and a coating of photoconductive material on one side thereof is electrically charged, the photoconductive side is then exposed to light coming from the indicia to form a latent image, an electrical connection is established between the exposed photoconductive coating and a body of electrostatically attractable toner, the toner is applied to the substrate on the side opposite the photoconductive coating to render the latent image visible.

6 Claims, 13 Drawing Figures

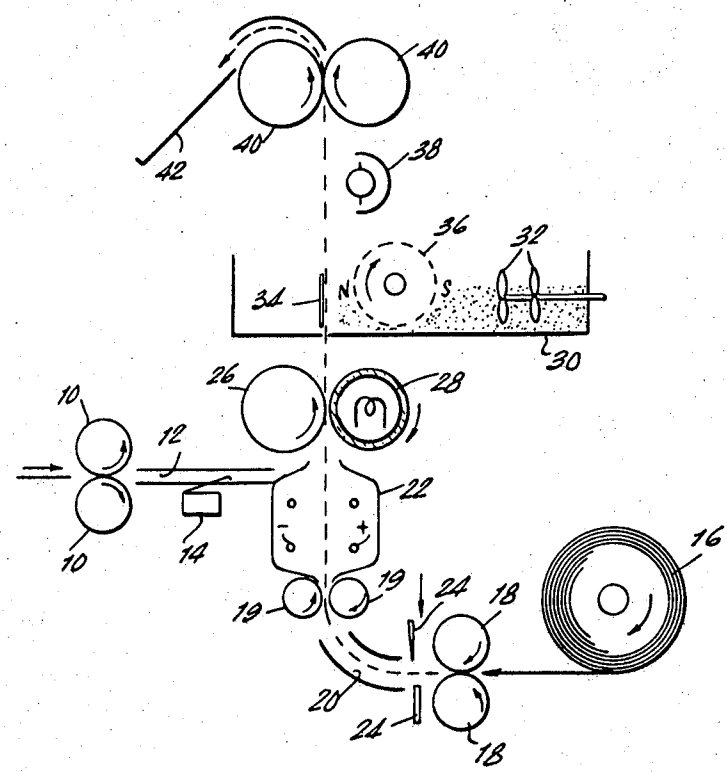


FIG. 1

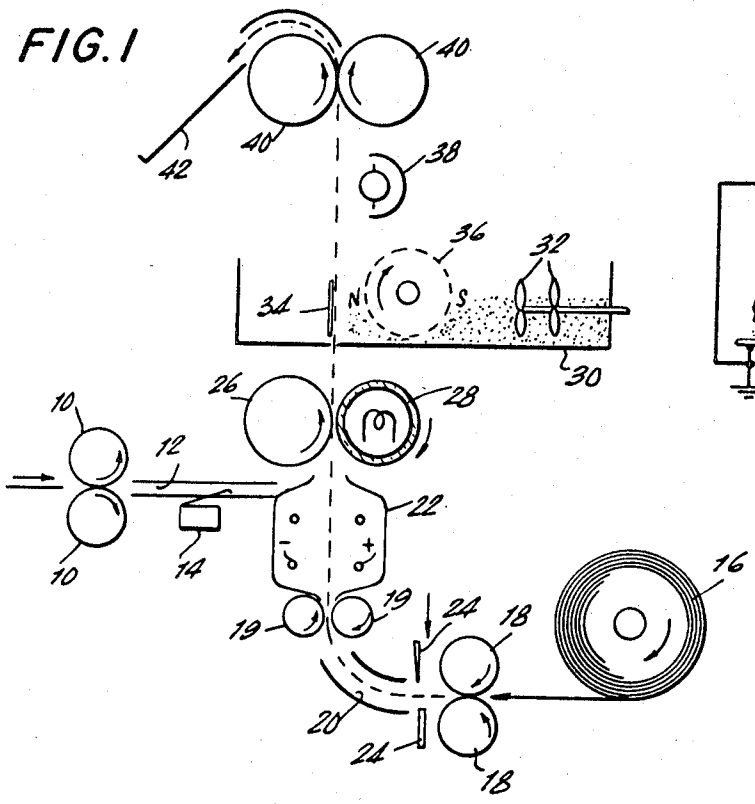


FIG. 2

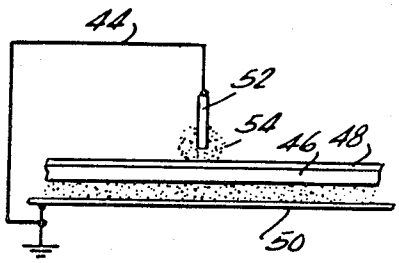


FIG. 3

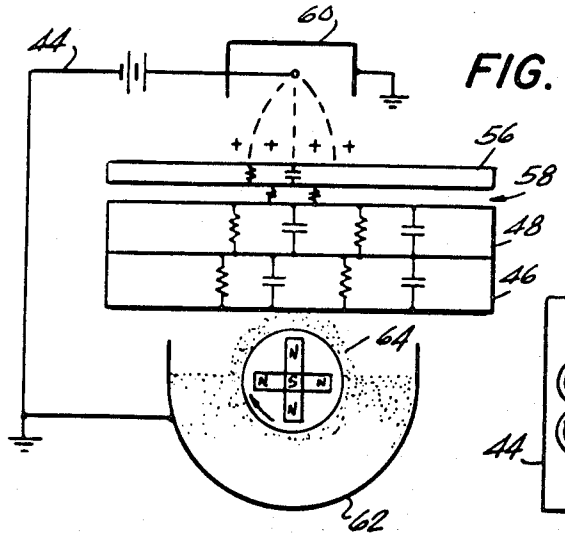
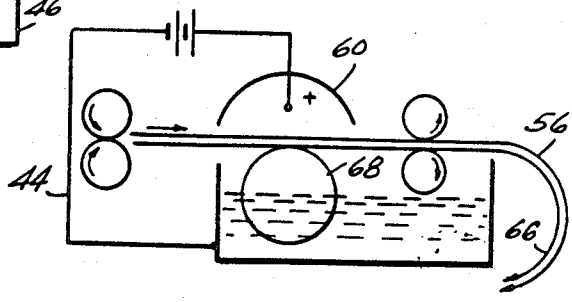


FIG. 4



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FIG. 5

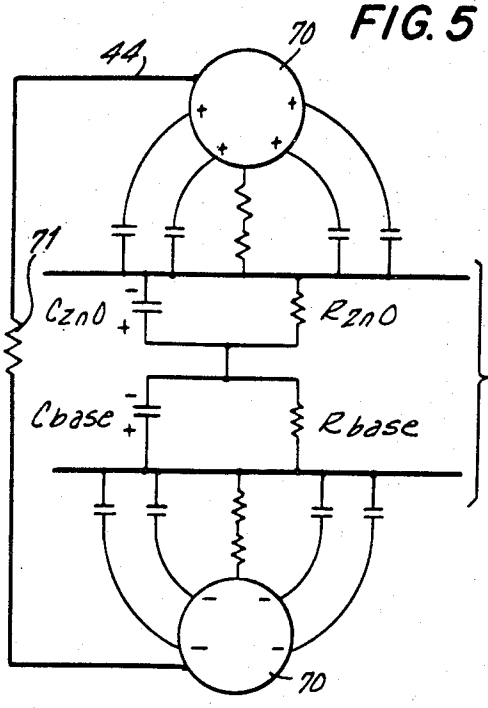


FIG. 6

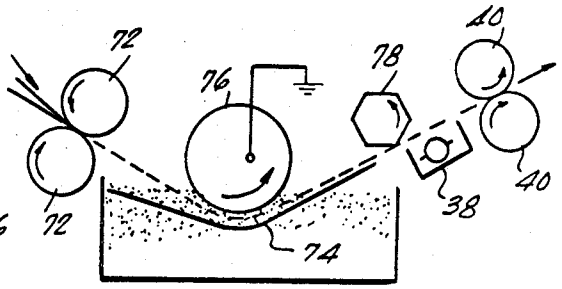


FIG. 8

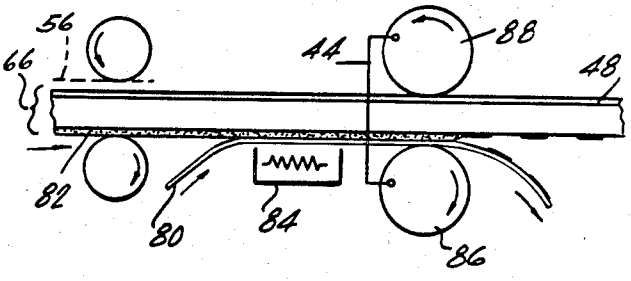


FIG. 7

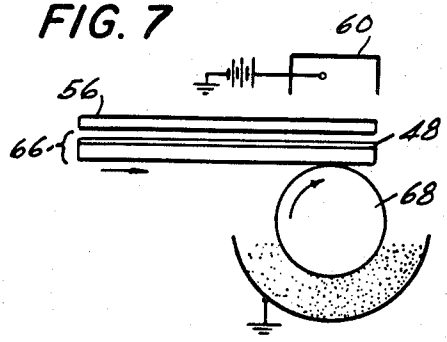
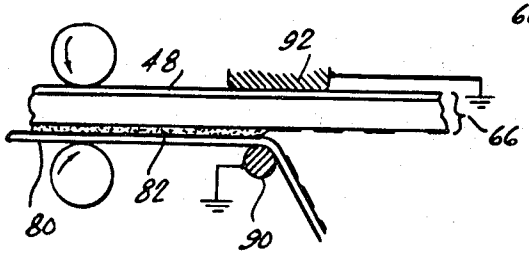


FIG. 9



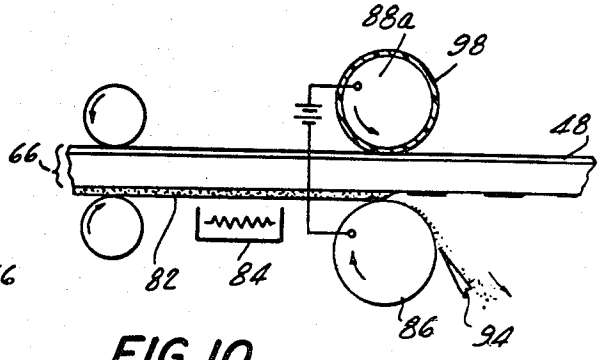


FIG. 10

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FIG. 11

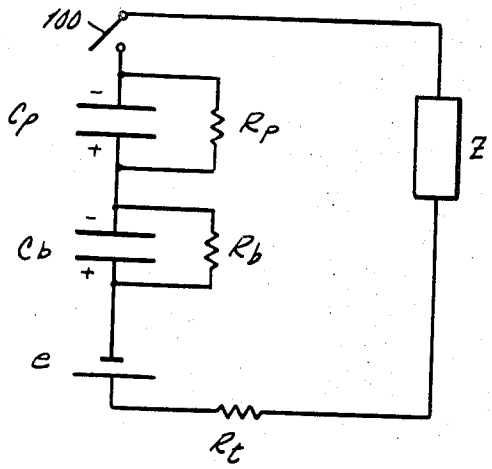
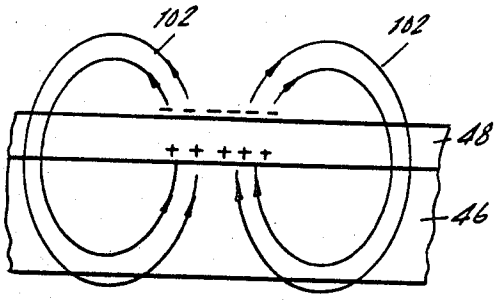


FIG. 12



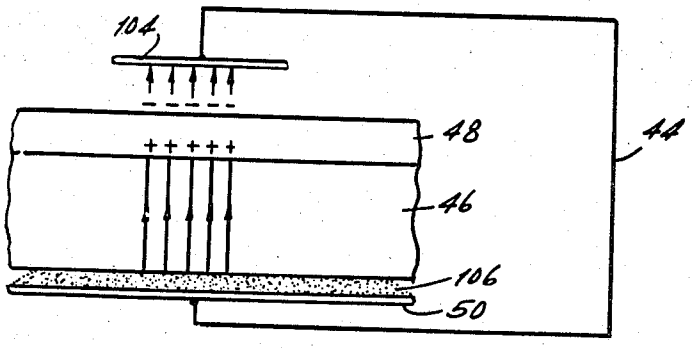


FIG. 13

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ELECTROSTATIC COPYING APPARATUS EMPLOYING DEVELOPMENT ON SIDE OF THE IMAGING SHEET OPPOSITE THE PHOTOCONDUCTIVE COATING

This application is a division of my application, Ser. No. 17,810 now Pat. No. 3,594,159 filed Mar. 9, 1970, in which I have described a number of embodiments of a novel process, in which a latent image in the form of a distributed pattern of electrical charges is produced by exposure to light of a photoconductive layer carried on a suitable sheet of substrate material, and in which the latent image is converted to a visible image by applying toner materials to the "rear" of the substrate sheet — i.e., the side opposite to that carrying the photoconductive material. As more fully set forth in said co-pending application, many of the disadvantages commonly experienced with conventional electrostatic reproduction systems as heretofore proposed, can be overcome by using the process disclosed and claimed therein, which involves the application of toner to the "rear" of the sheet.

This invention relates to electrostatic reproduction of documents and the like. In particular, this invention relates to novel methods for electrostatically reproducing images, and to apparatus for carrying out such methods.

In co-pending application, Ser. No. 17,810, filed Mar. 9th 1970; I have described a number of embodiments of a novel process, in which a latent image in the form of a distributed pattern of electrical charges is produced by exposure to light of a photoconductive layer carried on a suitable sheet of substrate material, and in which the latent image is converted to a visible image by applying toner materials to the "rear" of the substrate sheet — i.e., the side opposite to that carrying the photoconductive material.

As more fully set forth in said co-pending application, many of the disadvantages commonly experienced with conventional electrostatic reproduction systems as heretofore proposed, can be overcome by using the process disclosed and claimed therein, which involves the application of toner to the "rear" of the sheet.

Although these processes have proven very successful, certain difficulties may arise from time to time which result in the production of images not meeting the high standards of intensity and definition usually achieved by the use of these methods.

One difficulty sometimes experienced with reproduction according to my rear-of-sheet toning method is that there is a tendency for a reversed or negative image to be produced on the front, or photoconductive face, in addition to the positive image produced on the rear of the sheet (or vice versa). This is attributed to the fact that charge field lines, emanating from the charged areas of the photoconductive layer, pass downwardly into the discharged areas, attracting toner particles to these areas, as well as repelling the toner particles from the areas of the rear beneath the discharged areas of the photoconductive layer. Although this is not a serious disadvantage, it is advantageous to avoid the production of such images on the face of the photoconductive layer, when possible. This may be done by keeping the toner away from the face of the photoconductive layer, but is difficult to do when it is desired, for example, to tone the sheet by immersing it in toner.

Another difficulty sometimes encountered both in electrostatic copying techniques and in other copying systems is a tendency for some of the toner (or other pigment) to be deposited in the background areas where the copy should remain clear.

An object of this invention, therefore, is to provide improved methods and apparatus for reproduction of documents and the like.

Another object is to provide such method and apparatus which are effective to prevent the formation of undesired images by deposition of toner on the photoconductive face of the copy sheet.

Still another object is to provide methods and apparatus for improving the effective strength of the latent charge image at the rear of the substrate sheet.

A further object is to provide methods and apparatus as aforesaid, which reduce or eliminate the tendency for the formation of irregularities in the copy resulting from discharge arcs and sparks.

Yet another object is to provide methods and apparatus effective for electrostatic reproduction of documents and the like by reflex techniques.

Another object is to provide methods and apparatus effective to prevent deposition of pigment in background areas.

A feature of the invention is the use of a record medium comprising a substrate sheet and a layer of photoconductive material on said substrate.

Another feature is the provision of a low-impedance loop connecting the face of the photoconductive layer with a body of toner in contact with the rear of the substrate.

Another feature resides in the step of toning the copy sheet while the copy sheet is still in contact with the original.

Another feature resides in the step of separating the copy sheet from the original by a sliding as opposed to a peeling motion.

According to another feature of the invention, the copy sheet is sensitized for reflex exposure by charging it to a voltage, said voltage being so related to the exposing light level that said exposing light passing in a forward direction through said copy sheet is incapable of reducing said voltage to a value lower than that corresponding to a fully toned condition, and light passing in such forward direction added to light reflected back from the original, is sufficient to reduce said voltage to a value between the threshold value for toner deposition and the value corresponding to a fully-tone condition.

Another feature is the use of a toner having an appreciable voltage threshhold value, below which said toner will not be deposited on the copy sheet.

Still another feature resides in the step of providing for an appreciable degree of dark adaptation recovery in the photoconductive layer after exposure and before toning.

Another feature is the use of exposure light levels sufficiently low so as to leave all of the photoconductive material sufficiently highly resistive to prevent attraction of toner by low residual charges that may remain on the base material in background areas.

Yet another feature is the use of a ground loop with a corona contact to an original sheet in contact with the photoconductive layer.

Another feature is the step of discharging capacitive charges on the substrate by incorporating a photoconductive material in the substrate and subjecting the same to actinic radiation to render said substrate conductive and dissipate said capacitive charges, or prevent their formation in the first place.

A further feature is the step of providing triboelectrically neutral toner particles and depositing said particles on the copy sheet by attraction between the latent image charges on the copy sheet and induced charges of opposite sign produced on said particles by said charges on said copy sheet.

Another feature is the step of depositing toner on portions of a base sheet underlying discharged photoconductive material while avoiding deposition of toner on portions of said base sheet underlying charged photoconductive material.

Still another feature is the use of toner as a dispersion of toner particles in a thermoplastic material in the form of a film on the rear of a substrate sheet.

Other objects, features and advantages will become apparent from the following more complete description and claims and from the accompanying drawings.

The invention resides in the form, selection and arrangement of parts and of operating steps, as more fully described below and illustrated by way of the drawings.

In one particularly desirable aspect, this invention contemplates a method of reproducing indicia comprising in combination the steps of providing a record material in sheet form, said record material comprising an insulating substrate layer and a layer of photoconductive material on said substrate layer, electrostatically charging said photoconductive material, exposing said photoconductive material to an image in the form of actinic radiation, thereby producing a latent image of said indicia in the form of a distribution of electrical charges, providing an electrical connection between the surface of said photoconductive material and a body of toner in contact with the rear of said substrate, depositing an electrostatically attractable toner material on the rear of said substrate to form a visible image, and fixing said toner on said substrate to render said visible image permanent.

In another particularly desirable aspect, this invention relates to apparatus for reproducing indicia, said apparatus comprising means for electrically charging a sheet of electrostatic record medium, means for exposing one face of said sheet of record medium to an image of said indicia in the form of actinic radiation, thereby partially discharging said sheet and leaving thereon a latent charge image corresponding to said indicia, means for applying toner particles to the rear of said sheet, means for electrically connecting the exposed face of said sheet of record medium with said toner material in contact with the rear of said sheet through a low-impedance path, and means for fusing said toner particles to form thereof a permanent image.

The record medium used according to the present invention is a sheet of relatively insulating paper, plastic or the like, coated on one side with a photoconductive material. Various photoconductive materials suitable for the purpose are known to the art. One of the most effective, and therefore preferred, is zinc oxide, and the invention will be described primarily with reference to record media having photoconductive coatings of zinc oxide. Such photoconductive materials are readily available on the market under various trade designations, and they may be coated on suitable insulating substrates according to methods well-known in the art for coating conventional substrates.

The charging of the photoconductive layer is also done according to well-known techniques and using conventional equipment such as is used in various commercial electrostatic copying systems. Either a single or a double-corona charging system may be used, the double-corona charging system being generally preferred. Upon being charged (in the dark-adapted state), the photoconductive layer acquires a uniform electrostatic charge, acting in effect as a capacitor.

Upon exposure of the charged record sheet to a light image, the photoconductive layer becomes conductive, and the charge in the light-struck areas is dissipated, the charges of one sign at the top of the photoconductive layer being neutralized by those of opposite sign at the bottom of the same layer. In the areas unaffected by light, the photoconductive layer remains insulating and continues to act, in effect, as a capacitor dielectric, separating the (say) negative charges at the exposed surface of the photoconductive layer from the positive charges at the face thereof which is in contact with the substrate. The result is that the exposed surface presents a latent charge image, in the form of a mosaic of neutral (discharged) areas and charged areas. The lower face of the photoconductive layer presents the same charge pattern, except that the charges in the charged areas are opposite in sign to those at the outer surface.

As more fully explained in my aforesaid co-pending applications the (say) negative charges at the outer face are connected to the positive charges at the interface between photoconductive layer and substrate, by electrostatic field lines extending through the neutral, discharged areas. The field lines, as they pass through the rear of the substrate, constitute a charge image similar to that existing at the photoconductor-substrate interface, and of the same sign, and this charge image may be toned on the rear of the substrate, as more fully described and claimed in the aforesaid co-pending applications.

The foregoing description of the mechanism of electrostatic reproduction in general, and of rear-of-sheet toning in particular, is somewhat oversimplified, in that it overlooks the fact that the photoconductive layer does not remain fully charged in the areas not affected by light, nor does it become fully discharged in the light-struck areas. Rather, the photoconductive layer, after exposure, is charged over its whole extent, but the strength of the charge varies from point to point in correspondence with the latent image pattern. Thus, the conditions must be so adjusted that toner will deposit where the charge strength is high, but will not deposit where it is lower.

In accordance with the present invention, the contrast between the charge strength in image areas and that in background areas, considered from the rear of the sheet, is improved by providing a low-impedance path between the face of the photoconductive material and a body of toner in contact with the rear of the copy sheet. The effect of providing such a low-impedance path is two-fold; at the photoconductive surface, it pro-

vides a path for the charge field lines which draws them vertically away from the photoconductive layer, instead of passing through an air space over the photoconductive layer and down into the copy sheet in the adjacent discharged areas. Field lines thus entering the discharged areas tend to attract toner particles to these discharged areas, in the same manner that field lines entering the rear of the sheet tend to attract toner particles to the rear of the sheet. Toner particles attracted to the front create a reversed image. Providing a low-impedance path from the photoconductive surface to the toner in contact with the rear of the sheet provides an alternative path which prevents the field lines from entering the discharged areas of the photoconductive layer, and thus prevents such reversal toning.

Secondly, considering the situation at the rear of the sheet, the provision of a low-impedance loop to the toner in contact with the rear, results in a reduction of the resistance losses that occur when the field lines are forced to pass up through an air space adjacent the photoconductive layer, downwardly through the copy sheet, and back up through the copy sheet. By providing a low-impedance path as described, these resistance losses are cut down, and the field strength adjacent the rear of the substrate is correspondingly increased.

The above discussion relates to the behavior of triboelectrically charged particles. Triboelectrically neutral particles behave somewhat differently, as will presently appear. Also, the above remarks hold when the triboelectric charge on the particles is of the same sign as the charge applied during the charging step to the surface of the photoconductive material. When they are of unlike sign, there is formed a reversed image (as intended) on the rear of the sheet, and a positive (undesired) image on the front, as the toner particles are then attracted to the still-charged areas of the photoconductive layer.

The return loop, referred to herein as "low-impedance" path, is preferably a conductive path. However, it may be a low-impedance path formed by capacitive coupling of an array of dielectric elements such as glass beads, for example, which act in effect as capacitors connected in series. While not as effective as a conductive return loop to eliminate reversal toning on the front or to increase rear-of-sheet field strength, such a capacitive low-impedance path also represents an improvement over conditions heretofore proposed, wherein no return loop at all is provided.

According to the present invention, there is provided a low-impedance electrical connection between the surface of the photoconductive material and the rear of the substrate. This connection is most conveniently in the form of a wire loop, provided at one end with a connection to the face of the photoconductive layer and at the other with a connection to a body of toner in contact with the rear of the substrate, or base, sheet.

The connection between the wire loop and the photoconductive layer may be, for example, a magnetic brush — i.e. a bar magnet electrically connected to the wire loop and having at one end thereof an array of "bristles" composed of toner particles mixed with particles of iron or simply of iron particles alone. It may also be a metal roller in contact with the photoconductive layer and also connected electrically to the wire loop, or, it may take the form of a conductive plasma or corona of ionized gas particles, forming a conductive electrical connection between an original sheet in contact with the photoconductive layer and the wire loop.

The connection between the wire loop and the rear surface of the substrate may also take various forms, but for purposes of most embodiments of the invention, the connection will take the form either of a magnetic brush, as above described, containing iron particles mixed with particles of toner, or a bed of particles in contact with the surface of the rear of the copy sheet. In the latter case, the particles may be particles of toner mixed with iron particles, or triboelectrically neutral particles susceptible of acquiring induced charges as will appear more fully below.

The step of fixing the toner particles in place on the rear of the substrate is carried out according to conventional techniques and will most commonly be done by heating the toner particles (which are customarily admixed with a thermoplastic resin) so as to fuse the resin and bond the particles to the substrate. The heating may be done, for example, by infra-red radiant heating, according to methods well known to the art. Other methods of fixing may also be employed if desired for particular applications, for example, coating the deposited toner deposit with a fixative such as a spray mist of varnish, collodion, or the like.

Relative motion between the rear of the substrate sheet and the bed of toner should be avoided, as there is a tendency, when such relative motion takes place, for toner particles to be smeared off the sheet, and reattracted back to the magnetic brush or the like by normal triboelectric attractive forces, the capacitive charges which originally attracted the particles to the sheet having been at least partially dissipated in the process.

Various materials may be used as the substrate or base of the copy sheet, including paper and paper-like materials, and plastic films. The principal requirements of the substrate material are simply that it be physically acceptable as a copy sheet, and that it have a suitable volume resistivity. The resistivity of the substrate should be greater than 1×10^{10} ohm-cm, for example, between about 1×10^{12} and 1×10^{15} ohm-cm. The substrate should also have adequate hold-out so that the photoconductive material can be applied as a distinct surface layer, rather than penetrating appreciably into the sheet.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic representation of one type of apparatus according to the invention.

FIG. 2 is a diagrammatic representation of a portion of an apparatus according to the invention embodying a low-impedance current return loop.

FIG. 3 is a diagrammatic representation of an apparatus according to another embodiment of the invention employing a corona discharge as the conductive connection through the original and intervening air gap to the photoconductive surface and to the current return.

FIG. 4 is a diagrammatic representation of another embodiment of the apparatus according to the invention, employing a corona contact through the original and air gap to the photoconductive layer and a liquid toner in contact with the rear of the substrate layer.

FIG. 5 is a lumped analogue circuit equivalent diagram of a system according to the invention, utilizing triboelectrically neutral toner particles.

FIG. 6 is a diagrammatic representation of a form of apparatus according to an embodiment of the invention, for toning a copy sheet with triboelectrically neutral toner particles.

FIG. 7 is a diagrammatic representation of another form of apparatus according to the invention, for use with triboelectrically neutral toner particles.

FIG. 8 is a diagrammatic representation of another form of apparatus, designed to be used with a copy sheet having a dispersion of toner particles in wax or other thermoplastic material as a coating on the rear of the copy sheet.

FIG. 9 is a fragmentary diagrammatic representation of a modified form of the apparatus of FIG. 8.

FIG. 10 is a fragmentary diagrammatic representation of another form of apparatus designed to use a copy sheet having a coating of toner particles dispersed in thermoplastic material on the rear of the sheet.

FIG. 11 is a lumped analogue circuit equivalent diagram corresponding to FIG. 2.

FIG. 12 is a diagrammatic representation of the path taken by the latent image field lines in the absence of an effective low-impedance return loop.

FIG. 13 is a diagrammatic representation, analogous to FIG. 12, showing the alteration of the field line path brought about by providing a conductive return loop, according to the invention.

Referring now more particularly to FIG. 1, there is provided a pair of rollers 10, 10 or equivalent means for feeding an original into an original feed channel 12. In feed channel 12 there is also provided a sensing means such as microswitch 14.

A supply of copy paper in the form of roller 16 is provided, and means such as copy paper feed rollers 18 and 19 are provided for advancing copy paper from the roll into and through copy paper feed channel 20 and into double corona charge 22.

Means for cutting off a suitable length of paper are provided in the form of a cutter 24. The drive to feed rolls 18 and the actuating mechanism of cutter 24 are controlled through suitable electrical connections (not shown), by microswitch 14, so that when the switch is actuated by the leading edge of an original sheet, drive rolls 18 are started, and when the trailing edge of the copy sheet clears the microswitch, rolls 18 are deactivated and cutter 24 is activated to cut off from the roll the portion of copy paper thus far fed into copy paper feed channel 20.

The original and the copy paper sheet meet at the juncture where original feed channel 12 meets the exit aperture of charger 22, and both sheets are fed together into the nip between a soft back-up roll 26 and the transparent internally illuminated roll 28. As the papers pass between rolls 26 and 28, the copy sheet is reflex exposed by light passing through the copy sheet and reflecting off the original. The exposure conditions should be controlled, as in any reflex exposure process, in such manner that light passing through the copy sheet in the forward direction is insufficient to register an image, while the forward light, augmented by reflected light thrown back from the light areas of the original, is sufficient to record an image.

In the context of the present invention, this means that, assuming the photoconductive material to be zinc oxide, the copy sheet should be charged to a value well in excess of 150 volts (for example, around 400 volts), and the degree of exposure should be adjusted so that the forward light leaves the photoconductive layer charged to a minimum value of about 150 volts, and the reflected light further discharges the photoconductive layer to a range from about 50 volts threshhold value of toner) to about 150 volts (corresponding to a fully-toned image). These values are not intended to be limitative, as they will vary somewhat, depending on the photoconductive material the toner, and other conditions of operation. They are, however, given as representative of typical values which may be used successfully according to the invention.

After exposure, the sheets are passed upwardly through a mass of toner particles contained in a suitable reservoir 30. The toner particles may be, for example, triboelectrically negative particles of toner mixed with iron. Alternatively, the sheets may be separated before toning, for example, by the use of vacuum means, as described in my aforesaid co-pending application, and only the copy sheet passed through the toner.

Means such as agitators 32 are preferably provided to keep the toner mix in motion.

As the sheets pass through the toner mix, the back of the original is maintained in contact with a conductive back-up plate 34. Back-up 34 serves the purpose of helping to prevent excessive mechanical adherence or electrostatic attraction of toner particles to the rear of the original, and acts as part of the current return loop from the surface of the photoconductive layer to the rear of the copy sheet.

Toner particles are continuously passed in contact with the rear of the copy sheet by a rotating magnetic brush, indicated generally at 36, which moves at substantially the same peripheral speed as the linear speed of the paper.

It will be noted that, during the toning operation, there is a conductive path provided from the rear of the original sheet, through back-up plate 34 and the structure of reservoir 30, through magnetic brush 36 and the toner particles thereon, to the rear surface of the copy sheet.

As the two sheets, still adhering together, emerge upwardly out of toning reservoir 30, they pass an infra-red heater 38 or the equivalent, which fuses the deposited toner particles in place on the rear of the copy sheet. The sheets then pass together through exit rolls 40 into receiving tray 42, from which they may be removed and peeled apart.

In place of a roll of copy paper, a stack of sheets in a conventional sheet feeder may be used, in which case microswitch 14 or its equivalent serves to actuate the sheet feeder, as will be obvious to those skilled in the art.

FIG. 2 shows in diagrammatic fashion a portion of an apparatus according to the invention, in which the current return loop takes the form of a wire 44. In the arrangement illustrated, only the copy sheet is present, and this Figure therefore represents conditions obtaining when the copy sheet is charged, exposed and then separated from the original before toning. The copy

sheet as shown in FIG. 2 (with greatly exaggerated thickness) comprises substrate or base sheet **46** and photoconductive (e.g.ZnO) layer **48**. The rear of the base lies in contact with a bed of conductive particles of toner-iron mix, and the latter toner mix rests in electrical contact with a plate **50** of aluminum or other conductive metal.

The other end of the return wire is electrically connected to a magnetic brush comprising magnet **52** and a mass **54** of toner-iron mix (or simply of iron particles) adhering thereto, in contact with the photoconductive layer **48**. A lumped analogue circuit equivalent of the arrangement of FIG. **2** is shown below as FIG. **11**.

FIG. **3** shows, in diagrammatic form, a form of apparatus useful in toning a copy sheet while still in contact with the original, wherein contact between the face of the photoconductive layer and the current return is made through the original by way of a corona discharge. As shown in this Figure the original **56** is in facing relationship to the photoconductive layer **48** of the copy sheet, separated therefrom by a small, unavoidable air gap **58**. A corona is generated by means of positive corona charger **60**, and acts to accept electrons from the surface of photoconductive layer **48**, through the resistance offered by the air gap and the resistance and capacitance of the original. There is thus provided an electrical connection between the face of the photoconductive layer and the current return loop **44**, the latter being connected in turn to a reservoir **62** of toner, the toner reservoir being in electrical contact with the toner mix contained therein, magnetic brush **64** and the rear face of substrate **46**. Again, the magnetic brush should preferably have a peripheral speed substantially equal to the linear speed of the paper.

FIG. **4** shows, diagrammatically, a modified apparatus similar to FiG. **3**, but designed to be used with liquid toner. In this embodiment, original **56** and copy sheet **66** are fed between a corona produced by corona charger **60** and a kiss roller **68**, the latter being partially immersed in liquid toner and serving to transport liquid toner from the trough to the rear face of copy sheet **66**. The current return loop is similar to that of FIG. **3**, except that the connection to the rear of the copy sheet is through the kiss roller instead of the magnetic brush of FIG. **3**.

In the foregoing drawings, it has been assumed that the toner particles were triboelectrically charged, and hence attracted to either the positive or negative areas of the copy sheet. It is also possible, and sometimes advantageous, to use toner in the form of triboelectrically neutral particles — i.e. particles of pigment dispersed in a resin which is relatively conductive and in which a charge can be induced by an adjacent charge, e.g. an image, and does not have the property of triboelectricity — that is, of being preferentially charged either positively or negatively by friction. Using toner materials of this type, (which are available in the market), the attraction of the toner to the surface of the copy sheet results solely from the generation of induced charges. That is, a toner particle which comes in contact with or close proximity to a charged area on the copy sheet opposite sign, and the toner particle with its induced charge will then be attracted to the opposite charge on the copy sheet. Obviously, this only takes place where there is a charge on the copy sheet, and there is no reason for the triboelectrically neutral toner particles to migrate toward or adhere to the discharged portions of the copy sheet. This method is therefore advantageous, among other things, in that it helps to ensure freedom from toner deposits in background areas. Triboelectrically neutral materials suitable for this purpose are available, for example, from the Surface Process Co. of Dallas, Pa.

FIG. **5** illustrates, in schematic form, the situation obtaining when a triboelectrically neutral toner is used to tone a copy that has been charged, exposed, separated from the original, and then drawn through a bed of triboelectrically neutral toner. It will be noted that the toner particles **70** form deposits on both sides of the sheet in the undischarged areas, acquiring an induced positive charge at the photoconductor (ZnO) surface, where the charge on the copy sheet is negative, and an induced negative charge at the corresponding areas of the rear of the copy sheet, where the charge on the copy sheet is positive. It should be noted that the relative dimensions in FIG. **5** are greatly distorted for the purpose of clarity of illustration. Thus, the thickness of the sheet **66** may be of the order of 3 mils, i.e. 0.003 inch, whereas the air gap between toner particle **70** and the surface of sheet **66** may be, for example, of the order of one micron or less. The resistance **71** represents the resistance of the conductive path from particles at the face of the sheet, through the surrounding bed of toner particles, to the toner particles at the rear of the sheet.

FIG. **6** illustrates, diagrammatically, a form of apparatus designed to operate with triboelectrically neutral toner. In the operation of this apparatus, the original and copy paper are fed together (after exposure) into the toning portion of the machine via feed rolls **72** and are conducted by guides **74** through a trough of triboelectrically neutral toner, and in contact with a grounded, conductive rubber roller **76**. They are then conducted past means for mechanically knocking off any toner adhering mechanically to the uncharged portions of the sheet, for example, in the form of hexagonal roller **78**. Thereafter, the papers pass over infrared heater **38**, and out through exit rolls **40**, after which they may be peeled apart.

FIG. **7** illustrates diagrammatically a portion of another apparatus for toning copy sheets with triboelectrically neutral toner, in this case one which does not require that the original or the copy sheet be immersed in the toner. In the apparatus as illustrated in FIG. **7**, the copy sheet **66** which has previously been charged, placed in contact with the original **56** and exposed, is passed still in contact with the original into a toning zone between a corona generator **60** and a conductive kiss roller **68**, the corona generator and the kiss roller being connected through ground to form a conductive path between the face of the photoconductive layer **48**, through the original **56**, to ground and up through the toner reservoir and toner mix contained therein through the kiss roller **18** and toner on the upper surface thereof to the rear surface of the copy sheet. In case the toner material is not adequately conductive, the return loop from ground may be connected directly to the kiss roller. In such a case, inasmuch as neither triboelectric charging nor magnetic manipulation of toner particles is required, the usual admixture

of iron particles may be omitted, and the toner may consist of a triboelectrically neutral dispersion of pigment particles in a suitable resin.

Kiss roller **68** (which may, if desired, be a conveyor belt or the like instead of a simple roller), is provided with a conductive textured surface, for example an open weave wire cloth or the like which serves the dual purpose of serving as part of the current return loop and of effecting mechanical transport of toner mix from the trough to the rear of the copy sheet.

In the operation of the apparatus according to FIG. **7**, as the copy sheet and original pass through the toning zone, triboelectrically neutral particles are brought in contact with the rear of the copy sheet by the action of kiss roller **68** (or belt), and deposit thereon by virtue of charges induced on the toner by the charges on the copy sheet, assisted by the action of the current return loop. After passing through the toning zone the sheets are passed over an infra-red heater or the like (not shown in this view) and out of the apparatus, after which the original and copy sheets may be peeled apart. It will be noted that in this embodiment of the invention, the original is not required to be immersed in the toner as in the apparatus according to FIG. **6**.

FIG. **8** illustrates in fragmentary and diagrammatic form, certain details of a modified form of apparatus designed to use a prepared copy sheet having on the rear face thereof a coating comprising a dispersion of toner particles in a thermoplastic coating material such as paraffin wax, a low-melting polymer or the like.

In the operation of the apparatus as shown in FIG. **8**, the copy sheet **66**, which has already been charged and exposed is fed into the toning zone either with or without the original **56**, indicated in phantom. A suitable release sheet **80** of paper or the like is brought into contact with the thermoplastic toner-containing coating **82** on the rear of the release sheet, and while in contact therewith is passed over a heater **84** which may be a resistance heater or the like providing sufficient heat to melt the thermoplastic coating.

The release sheet should be relatively conductive, for example a metallized paper, or a paper which is kept sufficiently moist to be fairly conductive, or one which has been impregnated with salts or like materials to increase its conductivity, preferably having a volume resistivity of 1×10^{10} ohm-cm., or less.

While the thermoplastic coating is in the molten condition, the toner particles are free to migrate over the rear of the copy sheet and rearrange themselves thereon in accordance with the latent charge image and adhere to the rear of the copy sheet. Excess toner which remains in the areas underlying discharged areas of the photoconductive layer does not adhere strongly to the rear of the copy sheet and is carried off by the release sheet **80**. In this, as in the embodiments previously described the deposition of toner is assisted by a current return loop connecting the face of the photoconductive layer with the toner layer facing the rear of the copy sheet. In the embodiment of FiG. **8**, this is accomplished by means of a smooth metal roller **86** in contact with the underside of the release sheet, connected via conductor **44** to a metal roller **88** in contact with the photoconductive layer (or, if the original is still in place, preferably by a corona generator, as in the embodiment of FIG. **7**, for example).

As the copy sheet emerges from the toning zone, the thermoplastic medium cools to ambient temperature and resolidifies thereby fixing the toned image. In this case, it is not necessary to resort to a separate fusion step to fix the toned image. The toner dispersed in the thermoplastic coating may be triboelectrically charged by the thermoplastic material or a triboelectrically neutral toner.

FIG. **9** illustrates a compact embodiment of the apparatus of FIG. **8** suitable for use in a portable camera.

The embodiment of FIG. **9** is similar in construction and operation to that of FIG. **8**, differing mainly in that the heating element, for example a heated, grounded wire **90** also serves the function of roller **86** (FIG. **8**) as a part of the current-return loop, and in that the function of roller **88** (FIG. **8**) as part of the current-return loop is performed by a smooth, grounded metal plate **92**.

FIG. **10** illustrates still another modification of the apparatus of FIG. **8**, in which, instead of using a release sheet, the excess toner from the discharged areas is allowed to be carried off on the surface of roller **86** and is subsequently removed therefrom by a scraper **94** or equivalent means.

As also illustrated in FIG. **10** the upper roller **88** (here designated **88a**) may be provided with an insulative coating **98** of polytetrafluoroethylene ("Teflon") or similar material, in cases where it is desired to provide a bias in the ground loop to assist toner transfer during discharge and not have excess toner stick to the top roller or short out the bias when the rollers touch between copies or on the edges alongside the copies.

A difficulty that is occasionally experienced results from the strong attractive forces generated by the electrostatic charge on the copy sheet and the induced opposite charge on the original. When the two sheets are peeled apart prior to toning the copy sheet, it sometimes happens that arc or spark discharges occur. These discharges, which are visible in the dark, result in the discharge of areas of the copy sheet which should remain charged and the effects are visible in the finished copy as white stars, streaks, etc., where the toner has failed to be deposited on portions of the copy which should be dark.

It will be noted that in a number of variations of the method as illustrated by the drawings, the original is maintained in contact with the copy sheet until after the copy sheet has been toned and the toner fixed in place, e.g. by fusing. In these embodiments of the invention, the problem of image damage by reason of arcs or sparks is automatically eliminated, inasmuch as these phenomena occur only when the copy sheet is peeled away from the original and by that time the toner image is fixed and not susceptible to damage from this source.

In those embodiments of the invention where it is desired to separate the copy sheet from the original before toning, it has been found that arc and spark discharges can be greatly minimized or eliminated by separating the sheets by a sliding, as opposed to a peeling motion. This may be done manually or in a processing machine for example, by passing the paired sheets between a pair of rollers operating at differing peripheral speeds.

FIG. 11 shows a lumped analogue circuit equivalent diagram corresponding to the apparatus represented in FIG. 2. In FIG. 11, C_p represents the capacitance of the photoconductive layer, and R_p the resistance thereof, while C_b and R_b represent the capacitance and resistance, respectively, of the base, or substrate layer. The triboelectric charge of the toner bed is represented by e, and the resistance of the toner bed by R_t. The impedance of the return loop is represented by Z. A switch **100** may be interposed in the return loop, or the function of the switch may be performed simply by the act of completing the loop as shown in FIG. 2. In either event, when the copy sheet is charged, the photoconductive layer and the substrate layer are charged in proportion to their capacitances. Subsequent to charging, the capacitive charges dissipate at a rate inversely proportional to the resistivities — slowly in the base and the non-light-struck areas of the photoconductive layer, and rapidly in the light-struck areas of the photoconductive layer, where R_p is low due to the photoconductive effect.

On closing of the return loop, by closing switch **100** or otherwise completing the circuit, a redistribution of the charges takes place. In the non-light-struck areas, the capacitive charge on the photoconductive layer partially discharges into the base, decreasing the charge on the photoconductive layer and increasing that on the base, and thus increasing the charge available for attracting toner to the rear of the base. In the areas underlying the light-struck areas of the photoconductor, the charge on the photoconductive layer is small, and the value of R_p is also small, and the redistribution of charges amounts mainly to a discharge of the capacitive charge on the base through the photoconductive layer and the return loop.

FIG. 12 illustrates, diagrammatically, the path taken by the latent image field lines in an exposed copy sheet, in the absence of an effective low-impedance return loop — for example, when the sheet is suspended in air. The charged area, corresponding to a non-light-struck area, is indicated by the "+" and "−" signs. According to the convention adopted, the field lines **102** are considered to emerge from the sheet in the areas bearing negative charges, and to re-enter the sheet in the adjacent uncharged areas, as indicated by the arrowheads. As shown in FIG. 12, the field lines traverse a high-resistance path including an air space over the photoconductive layer, a downward passage through the insulating substrate **46**, an air space under the substrate, and an upward return passage through the substrate. If the substrate is made more resistive, the field lines tend to extend further to the rear, but the total resistance of the path is increased, thereby diminishing the discharge current available to attract toner particles. On the other hand, if the substrate is made more conductive, there is a tendency for some of the field lines to be shorted out through the substrate without reaching the rear surface, as also indicated in FIG. 12. Field lines thus shorted out are not effective to attract toner particles to the rear of the substrate.

FIG. 13 illustrates the manner in which the path of the field lines is altered when a low-impedance return loop is provided according to the present invention. On emerging from the negative, charged areas of the photoconductive layer, the field lines, (instead of re-entering the sheet through adjacent uncharged areas), pass into a conductive contact member, represented in this Figure by a metal plate **104**, through the conductive return, represented by wire **44**, into a lower contact such as metal plate **50**, and through the bed of toner particles **106** into the rear of substrate **46** and upwardly therethrough. The overall resistance of this path is much lower than that shown in FIG. 12. Moreover, the field lines adjacent the rear surface of the sheet are straightened, resulting in improved definition, and the presence of field lines entering the discharged areas of the photoconductive layer, and tending to attract toner particles to these areas, is avoided.

In addition to the use of a conductive return loop as described above, various other steps may be taken to improve the deposit of toner on the copy sheets and particularly to avoid toner deposition in background areas.

One such step is to provide for a partial return of the photoconductor to the dark-adapted state. This may be done, for example, by using a zinc oxide-resin system having a rapid dark adaptation characteristic, and/or by introducing a time interval between the exposure and toning steps, and/or by hastening the dark recovery between exposure and toning by exposing the exposed copy to moderate infra-red heating or to an ozone discharge, etc. The operating conditions for these steps are highly interdependent, and therefore cannot be specified in terms of unique operating ranges. They may, however, be established for any given installation by simple routine experiments, to find levels such that the background is printed clear while the dark areas remain fully toned.

The object and effect of all these steps is to either reduce the charge that may have been left on the insulative base and/or to raise the volume resistivity of the photoconductive layer in the light-struck areas so that charges that may have been left on the insulative base will not be able to produce sufficient current flow to cause toner to transfer over from the toner mix to the rear of the sheet. By way of example, a time lag on the order of 30 seconds between exposure and toning is frequently helpful in eliminating deposition of toner particles in background areas. This allows the charge stored on the base sheet to discharge through its own internal leakage paths and allows the light-struck areas of the photoconductor to revert partially to the dark-adapted state. As the time constant of the base is an order of magnitude or two less than that of the dark-adapted photoconductive layer, no significant amount of image charge is lost during this time.

Another expedient useful to prevent deposition of toner in background areas is to incorporate a photoconductive material in the material of the substrate layer. This is based on the fact that the base material, as well as the photoconductive layer, receives an electrostatic charge during the charging step, and the charge on the base material, although of smaller magnitude than that on the charged photoconductive material, may in some cases be sufficient to attract toner particles. With a photoconductive material in the base or substrate layer the latter may be exposed to light either before, during or after charging or during or after the exposure step resulting in either prevention of a charge build-up or dissipation of the charges on the

base and thus reducing or eliminating the tendency for toner particles to adhere to the base in areas underlying discharged areas of the photoconductive layer. Such a photoconductive material may be for example a dispersion of zinc oxide particles in a resinous binder in the base sheet. The base sheet photoconductor may or may not be sensitized to the same frequencies of radiation as the photoconductive layer.

INVERSION PRINTING

In a variation of the process of this invention, "inversion" toning, or the deposition of toner particles in background areas, can be made the basis of a method for the production of reversed copies. For this purpose a relatively highly-insulating substrate material is used, which is capable of holding an appreciable portion and preferably a major portion of the charging voltage. The photoconductive layer and the substrate are charged in the usual manner, and the photoconductive layer is exposed thereby discharging the light-struck areas thereof. After exposure, the latent charge image (considered from the rear of the substrate) is in the form of an overall charge on the substrate, but in which the resistance of the photoconductive layer is low enough to permit toning in the light-struck areas but high enough to prevent toning in the non-light-struck areas where the photoconductor remains highly resistive. It is also slightly charged, but this additional charge in the toning circuit is not sufficient to cause toner to be drawn over to the rear. On toning such a latent image (assuming that the original charge was negative on the face of the photoconductive layer and that a negatively-charged toner is used), the toner will deposit only in the light-struck areas producing a negative of the exposing image.

The methods and apparatus of the present invention provide an improved reproduction system for copying documents and the like. They minimize or eliminate the tendency for spark or arc discharges to interfere with the quality of the copy and they are adapted to reflex exposure methods.

While this invention has been described in terms of certain preferred embodiments and illustrated by way of certain drawings, these are illustrative only, as many alternatives and equivalents will readily occur to those skilled in the art without departing from the spirit or proper scope of the invention. The invention is therefore not to be construed as limited except as set forth in the appended claims.

Having thus fully described the invention, what is claimed as new and desired to be secured by Letters Patent of the United States, is:

1. Apparatus for reproducing indicia, said apparatus comprising means for electrically charging a sheet of electrostatic record medium, means for exposing one face of said sheet of record medium to an image of said indicia in the form of actinic radiation, thereby partially discharging said sheet and leaving thereon a latent charge image corresponding to said indicia, means for applying toner particles to the face of said sheet opposite the latent charge image face, means for electrically connecting the exposed face of said sheet of record medium with said toner material in contact with the face of said sheet opposite the latent image through a low-impedance path, and means for fusing said toner particles to form thereon a permanent image.

2. Apparatus according to claim 1, wherein said means for electrically connecting the exposed face of said sheet of record medium with said toner in contact with the opposite face of said sheet comprises a metallic contact member in contact with said exposed face of said sheet.

3. Apparatus according to claim 1, wherein said means for electrically connecting said exposed face of said sheet to said toner in contact with the opposite face thereof comprises a mass of magnetic, conductive particles adhering to a magnet, said particles being in contact with the exposed face of said sheet, said magnet being electrically connected to said toner in contact with the opposite face of said sheet.

4. Apparatus according to claim 1, wherein said means for electrically connecting said face of said sheet to the rear thereof comprises a conductive corona of ionized gas molecules, said corona being in conductive contact with an original sheet in facing relation to said sheet of record medium and connected by a conductive path with toner in contact with the rear of said sheet.

5. Apparatus according to claim 1, wherein said means for electrically connecting said face of said sheet to the rear thereof comprises means for immersing said sheet in a mass of toner.

6. Apparatus according to claim 1 in which the sheet comprises a photoconductive medium.

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